Technical Report M3

SIDE CHANNEL SEDIMENTATION STUDY OF THE MISSISSIPPI RIVER MARQUETTE CHUTE/CAPE BEND RIVER MILES 51 TO 47

HYDRAULIC MICRO MODEL INVESTIGATION

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Prepared for
U.S. Army Corps of Engineers Avoid and Minimize Program,
U.S. Fish and Wildlife Service

In cooperation with
Illinois Department of Natural Resources
Missouri Department of Conservation Long Term Resource Monitoring Station

December 1997

DISTRIBUTIO[illegible] A
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Distributi[illegible]

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
xx-12-1997

2. REPORT TYPE
Final Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Side Channel Sedimentation Study of the Mississippi River,
Marquette Chute/Cape Bend, Hydraulic Micro Model Investigation

Volume : 1

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
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US Army Corps of Engineers
St.Louis Dist
Applied River Engineering Ctr
Foot of Arsenal St
St. Louis , Missouri 63118

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report M3

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District,
St. Louis
1222 Spruce St
St. Louis , Missouri 63103

10. SPONSOR/MONITOR'S ACRONYM(S)
U.S.ACE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
A Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

14. ABSTRACT
A sedimentation study of the Mississippi River, between River Miles 51 and 47, was conducted to study the mechanics of Marquette Chute. A hydraulic micro model was used to access a variety of structural design alternatives to develop biological diversity in the side channel. The study found that favorable diversity could be developed by the construction of two notches in the upper closure structure of Marquette Chute, and by the construction of two dikes below the lower closure structure of Marquette Chute.

15. SUBJECT TERMS
Sedimentation; Marquette Chute; Mississippi River; Cape Bend; Side Channel; Dikes

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	Unclassified Unlimited	49	Robert D. Davinroy
					19b. TELEPHONE NUMBER *(include area code)* 314-263-4714

INTRODUCTION

A sedimentation study was initiated in order to evaluate a number of environmental design alternatives and modifications in a particular side channel of the Middle Mississippi River. The study of Marquette Chute was sponsored by the St. Louis District Avoid and Minimize Program. The total study area consisted of a 6 mile reach of river, between River Miles 53 and 47.

The study was conducted during the period between January 1997 and July 1997. The study was performed by Mr. Robert Hetrick and Mr. Dave Gordon, Hydraulic Engineers, under direct supervision of Mr. Robert Davinroy, District Potamologist for the St. Louis District.

Personnel also involved and overseeing the study included Mr. Claude N. Strauser, Chief of the Potamology Section, Mr. Steve Redington, Chief of the River Engineering Unit, and Mr. Ron Yarbrough, Avoid and Minimize Program Manager.

Personnel from other agencies involved in the study included:
Mr. Butch Atwood, Illinois Department of Natural Resources, Ms. Jenny Frazier, Mr. Bob Hrabik, Mr. Mike Petersen, Mr. Dennis Herzog, Mr. Mark Boone, and Ms. Lesly Conaway, Mr. Mark Haas, Mr. Gordon Farabee, Mr. Ken Brumett and Mr. Ken Dalrymple, Missouri Department of Conservation, Mr. Bob Clevenstine and Ms. Joyce Collins, U.S. Fish and Wildlife Service.

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BACKGROUND

This report details the investigation of a sedimentation study using a physical hydraulic micro model. The micro model methodology was used to evaluate existing conditions and various design measures to improve the riverine habitat in the Marquette Chute reach of the Mississippi River (Miles 53 to 47).

A team of cooperating federal and state agencies assembled at the U.S. Army Corps of Engineers Applied River Engineering Center (AREC) in St. Louis, Missouri to formulate and conceptualize measures to enhance and/or restore the side channel at Marquette Island (Plate 1). A variety of environmental design alternatives were submitted. The main goal was to evaluate the positive impacts of these alternatives, if any, on the resultant bed configuration (sediment transport response) and flow patterns within the Mississippi River study reach. Creating desirable biological diversity while at the same time ensuring a reliable navigation channel was the major challenge of this study.

1. Problem Description

The present day bed configuration of the side channel at Marquette Island is illustrated in Plate 2. The bathymetry showed that the overall depths of the side channel were relatively shallow as compared to the main channel (plates 3,4, and 5). The shallow depths were attributed to a combination of natural and man induced effects. Because the side channel lied essentially on the inside of a bend, the river's natural tendency was to cause sedimentation throughout the side channel while deepening the main channel. The placement of the two closure structures across the side channel further accentuated the river's natural processes.

The lower half of the side channel displayed above average depths. Two existing dike structures have impacted this development. A hardpoint was added to a remnant closure structure at River Mile 49.6(L). This hardpoint has generated scour off its tip.

Flow now generally deflects off this structure and has a tendency to cross over to the right descending bank of the side channel. One mile downstream from this original remnant structure, there exists a historical closure structure. This structure was constructed originally of pile in 1933. Rock was later added in 1972. There is approximately a 75 foot wide, naturally created, notch near the center of the closure structure. This notch tends to pull current from the right descending bank toward the left descending bank.

A site inspection was performed by Robert Hetrick in January of 1997. Photos were taken and are shown in Plates 6 and 7. The river stage at Cape Girardeau was approximately 20.7 which was slightly above mid-bank. Plates 8, 9, and 10 show aerial photographs that were taken by LTRM personnel on May 1st when the river stage at Cape Girardeau was approximately 2 feet above flood stage. It is important to note the relatively large area and amount of sediment that was still above the water surface.

2. Study Purpose and Goals

The purpose of this study was to address the sediment transport response and interaction between the main channel and side channel of the Mississippi River, and to analyze design alternative impacts within the side channel.

The goal was to develop increased aquatic diversity in the side channel in the form of increasing depth diversity. Several different design schemes were tested in the model and compared to an established base condition.

MICRO MODEL DESCRIPTION

1. Scales and Bed Materials

Plate 13 is a photograph of the hydraulic micro model used in this study. The model insert encompassed the river channel between River Miles 56 and 45. Entrance and exit conditions in the model were adjusted. The actual study reach was between river miles 53 and 47. The scales used were 1 inch = 800 feet, or 1:9600 horizontal and 1 inch = 65 feet, or 1:780 vertical for a 12.3 distortion ratio. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.23.

2. Apperturences

The model was constructed according to 1994 aerial photographs of the river. In all model tests, the effective discharge or hydrograph was simulated (2). Discharge hydrographs were simulated and controlled automatically by a computer system developed at AREC. Stages were monitored and resultant model bed configurations were measured and recorded with a 3-dimensional digitizer.

MICRO MODEL TESTS

1. Calibration and Verification

The calibration/verification of the micro model involved the adjustment of water discharge, sediment volume, hydrograph time scale, and slope. These parameters were refined until the measured bed response of the model was similar to the prototype.

A. Design Hydrograph

Because of the constant variation experienced in the prototype, a design hydrograph was used to theoretically analyze the average expected sediment response during any given year. The time increment or duration of the design hydrograph was 3 minutes.

B. Prototype Surveys

Several prototype surveys were used to determine the general bed characteristics that existed in the prototype (Plates 2, 3, 4, and 5). In the perusal of both the model and the actual river surveys, it was discovered that a certain amount of non-erodible material existed throughout this particular study reach. This was confirmed in interviews with St. Louis District Corps dredging personnel. Between River Miles 52.6 and 51.7, a rock ledge extended off the right descending bank. The exact limits of this ledge have not been explored nor mapped, but from conversations with both dredging and river industry personnel, interrogation of 1988 ice photos (Plates 11 and 12), and from scour development in the model, the rock ledge appeared to extend approximately 400 feet out into the river channel. The effects of this ledge were visually apparent on the 1988 ice photos, and was a major influence to the sediment transport and ultimate bed configuration (scour and depositional patterns) in the vicinity of Cape Girardeau.

There was also a fair amount of non-erodible bed in the form of clay deposits and or rock outcroppings near River Mile 50. This was verified by further conversations with

dredging personnel. The ice photos and hydrographic surveys showed that the expected apex scour of the bend at River Mile 49.8 was non existent and was actually occurring further down the bend at River Mile 49.0. The model verified the existence of this non-erodible area by producing an overabundance of scour at River Mile 49.8 as compared to the prototype.

These two apparent non-erodible areas of the prototype were compensated for in the model by the placement of oil-based clay. The model was adjusted until stability was achieved. It was evident that by placing these clay areas into the model, the bed response both upstream and downstream behaved more similar to that observed in prototype.

Once a favorable comparison of several surveys of both the prototype and model were made, the model was considered calibrated. The resultant survey of this bed response served as both the verification and base test of the micro model (1).

2. Base Tests

In 1995, a series of Bendway Weirs were constructed in the between miles 48.3(R) and 49.5(R). Because two of the three main channel prototype surveys were conducted before the bendway weir-field was in place, there was a need to conduct two base tests. The model was calibrated first without the weirs. After the model was calibrated under this condition, the weir-field was then added. The model was calibrated again with the weirs in place. This second base test served as a comparison for all future tests.

A. Base Test Without Weirs

Plate 14 shows the resultant bed survey of the base test without the bendway weirs. In the beginning of the study reach, the thalweg developed off the left descending bank. A scour hole was observed below dike 53.0(L). A crossing developed from

approximately river mile 52.8 to 52.1. The thalweg remained off the right descending bank throughout the rest of the study reach. Scour was also present near mile 51.4 on the right bank and below the apex of the bend near the diversion channel at mile 48.9. The last major area of scour observed in the model occurred off the tip of dike 47.9(R), just below SEMO port. A bar developed on the left descending bank from mile 52.8 to 51.8. A second bar developed at mile 51.3, outside the upper closure structure of Marquette Chute and continued downstream to the end of Marquette Island.

The model also showed very similar trends in the chute as compared to the prototype. There was a small scour hole inside the upper end of the upper closure structure near the existing notch. The deep section of the chute followed the Illinois side of the chute downstream toward the existing hardpoint. A scour hole was observed at this dike. Along the upper end of Marquette Island, a very high bar developed. This bar was vegetated in the prototype. Below the existing hardpoint, the "channel" crossed to the island side of the chute. There was a deep scour hole below the lower closure structure. Below the scour hole, there was a bar that extended through the remainder of the chute toward the confluence with the main channel. The only area in the model that did not accurately reflect the prototype was the area just above the lower closure structure. In the model, there was a large scour hole that formed that was not evident in the prototype. However, this scour hole remained constant throughout all tests. It is believed that this anomaly did not significantly effect the results of any of the tests.

B. Bast Test With Weirs

Plate 15 shows the resultant bed survey of the base test with the Bendway Weirfield added. As with the original base test, the model displayed favorable results when compared with the prototype data. The side channel showed no significant changes as compared the original base test. In addition, the main channel showed no significant changes with the exception of the bendway weirfield. In this area, the right bank appeared to have caught additional sediment. The point bar also receded approximately 75 feet when compared to the base test without the weirs.

3. Alternative Plans

A number of alternative design plans were tested in the model. As previously discussed, all tests were initiated in the hopes of creating environmental diversity and enhancement in the side channel while at the same time ensuring the integrity of the navigation channel. The effectiveness of each design plan was evaluated by comparing to the base test condition.

Alternative A. Upstream Angled, Blunt Nosed Chevrons at Mile 50.5(L).

Plate 16 is a plan view contour map of the resultant bed configuration of Alternative A. Results indicated that a marginal amount of deepening occurred near the chevrons (5 to 10 feet), the scour was very local, and had little if any effect on overall deepening of the side channel. The scour hole immediately downstream of Dike 49.6L shallowed approximately 10 feet due to the material being moved by the chevrons. The rest of the side channel remained relatively unchanged.

Alternative B. Downstream Angled, Blunt Nosed Chevrons at Mile 50.5(L).

Plate 17 is a plan view contour map of the resultant bed configuration of Alternative B. Results indicated that between Mile 50.6L and Dike 49.6L, an overall deepening of the side channel occurred. Depths increased 5 to 10 feet in this region. Between Dike 49.6L and Dike 47.6L, the channel shallowed 5 to 10 feet. Shallowing was also noticed directly downstream of all river structures, and was observed in the model to be a direct result of the localized displaced sediment lost from the upstream chevron field.

Alternative C. Upstream Angled Chevrons at Mile 50.1(L).

Plate 18 is a plan view contour map of the resultant bed configuration of Alternative C. Results indicated the chevrons had no effect on side channel depth. The scour holes downstream of Dikes 49.6 L and 48.6 L became slightly deeper as compared to the base test.

Alternative D. Lowering Upper Closure Structure to +10 LWRP.

Plate 19 is a plan view contour map of the resultant bed configuration of Alternative D. Model tests revealed that lowering the upper closure structure 10 feet caused the loss of adequate depths in the adjacent navigation channel. Some depth was gained in the upper end of the side channel (0 to 5 feet) from the closure structure to Dike 49.6L. The depths and sediment distribution of the remaining part of the side channel remained mostly unchanged as compared to the base test.

Alternative E. Two Notches in Upper Closure Structure.

Plate 20 is a plan view contour map of the resultant bed configuration of Alternative E. Results indicated that both the side channel and navigation channel remained relatively unchanged. Some minor increases in depth were experienced locally at the new downstream notch, but the scour hole created was very marginal in depth (5 to 10 feet). The rest of the side channel remained mostly unchanged.

Alternative F. Upstream Angled Blunt Nosed Chevrons and Two Notches in Closure Structure.

Plate 21 is a plan view contour map of the resultant bed configuration of Alternative F. Results indicated that some deepening occurred directly below the notches (10 to 20 feet). Minor deepening also occurred in the upper end of the side channel, from just downstream of the most upstream notch to Dike 49.6 L.

Alternative G. Lower Closure Structure Lowered 10 feet and Two Notches in Upper Closure Structure, Upstream Angled Blunt Nosed Chevrons.

Plate 22 is a plan view contour map of the resultant bed configuration of Alternative G. Results indicated that the lower one half of the side channel had a tendency to shallow. In the upper end of the channel, the scour below the notches was between 10 and 20 feet. A slight deepening (5 to 10 feet) occurred between the upper closure and dike 49.6 L. The adjacent navigation channel remained mostly unchanged.

Alternative H. Longitudinal Dike and Two Alternating Dikes, Two Notches in the Upstream Closure.

Plate 23 is a plan view contour map of the resultant bed configuration of alternative H. Results indicated that a somewhat deeper channel (5 to 10 feet) developed through the upper half of the side channel. The scour hole at Dike 49.6 shallowed approximately 10 feet.

Alternative I. Existing Dike Raised to Top of Bank.

Plate 24 is a plan view contour map of the resultant bed configuration of Alternative I. Increasing the height of the dike caused excessive deposition in the middle of the side channel, on the order of 10 to 15 feet. Excessive scour was also created around the tip of the dike.

Alternative J. Large Notch in Upper Closure Structure and Chevron Below Notch.

Plate 25 is a plan view contour map of the resultant bed configuration of Alternative J. Notching the upper closure structure caused some light scouring (5-10 feet) immediately behind the closure structure. The changes also caused some deposition (5-10 feet) between Dikes 52.1L and 51.8L, and around Dikes 51.4L and 51.0L in the main channel. Noticeable scour in the centerline of the main channel between river miles 52 and 51 was observed. A scour hole also developed between Dikes 47.9R and 47.8R. The changes caused some scour around the outside of the bend from Dike 47.9R to the end of the study reach. The scour area around Dike 48.6L in the side channel increased slightly, and some small areas at the end of the side channel increased slightly in depth.

Alternative K. Notch in Upper Closure Structure.

Plate 26 is a plan view contour map of the resultant bed configuration of Alternative K. A large amount of scour was observed throughout the length of the main channel after notching the upper closure structure. Scouring also occurred around the outside of the

bend near Dikes 47.9R and 47.2R. The changes also caused uniform deposition of approximately five feet through most of the side channel. Localized scour was noted around the notched closure structure, as expected.

Alternative L. Bendway Weirs Opposite Upper Closure Structure. (550' Length)

Plate 27 is a plan view contour map of the resultant bed configuration of Alternative L. Scour was noted about one mile upstream from the installation of new bendway weirs. The weir construction increased scour around Dike 53.0L at the beginning of the study reach. Noticeable deposition occurred on the inside or left of the channel around the existing dikes. The side channel was not surveyed.

Alternative M. Installation of Ten Bendway Weirs. (1000' Length)

Plate 28 is a plan view contour map of the resultant bed configuration of Alternative M. The results from Alternative M are very similar to those observed in Alternative L, although the scour pattern created upstream of the weirs was shorter and wider. Similar deposition on the left side of the channel occurred, as well. Most importantly, a large scour hole developed at the entrance to the side channel.

Alternative N. Removal of Lower Closure Structure.

Plate 29 is a plan view contour map of the resultant bed configuration of Alternative N. Removal of the lower closure structure caused scour in the main channel near the entrance to the side channel. Some erosion occurred downstream of the newly removed closure structure. Deposition was noted in the main channel at the end of the side chute.

Alternative O. Two Dikes Downstream of Lower Closure Structure.

Plate 30 is a plan view contour map of the resultant bed configuration of Alternative O. The installation of two dikes in the side channel caused some deposition directly adjacent to the structures.

Alternative P. Four Dikes Downstream of Lower Closure Structure.

Plate 31 is a plan view contour map of the resultant bed configuration of Alternative P. The installation of four dikes in the side channel caused some scour around the new structures and approximately ten feet of deposition just downstream of the dikes.

CONCLUSIONS

The following is a summary of findings and recommendations of the model study:

- The chevrons and dikes in alternatives A,B,C,F,G,H, and I produced minimal scour. This was due to the fact that there was very little sediment transport energy throughout the side channel even when the closure structures were lowered or notched.
- The placement of the three chevrons in alternative C did not significantly change the bed characteristics of the bar. There is very little sediment transport energy in the side channel near Marquette Island. This is evident in the photographs of the side channel during high water (Plates 8, 9, 10).
- Some positive benefits were seen in alternative D through the upper end of the side channel, however lowering the closure structure adversely effected the navigation channel.
- In alternatives E, J, and K, the notches in the upper closure structure created deep, localized scour holes without compromising the navigation channel. These notches however, did not significantly enhance habitat throughout the rest of the side channel.
- Lowering or removing the lower closure structure in alternatives G, and N, produced minor positive effects throughout the side channel, however, the large scour below the lower closure structure was lost.
- Raising dike 47.6 (L) in alternative I caused increased sedimentation upstream of the dike.
- The Bendway Weirs in alternatives L and M did not ensure a navigation channel in order to lower the upper closure structure. This was because of the lack of cross section needed to allow the weirs to work effectively.
- Alternatives O and P created a small channel connecting the scour hole below the lower closure structure with the main navigation channel.

In the interpretation and evaluation of the tests conducted in this study, it should be remembered that the results of these model tests were qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of unknown underlying rock formations or other nonerodable variables.

Finally, it should be noted that the innovative ideas set forth in this study were developed as a result of a cooperative effort between all of the aforementioned agencies. "Hands on" experimentation at the Applied River Engineering Center (Plate 1) enabled both biologists and engineers to formulate design alternatives and conduct experiments in the micro model.

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2. Leopold, Luna B., A View of the River, Harvard University Press, Cambridge Massachusetts, London, England, 1995.

APPENDIX

Plates 1 through 31 will follow.

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CHECKED BY R DAVINROY

DATE 4 AUGUST 1997

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Engineers and Biologists Formulating Ideas on the Marquette Chute Micro Model

PLATE NO 1

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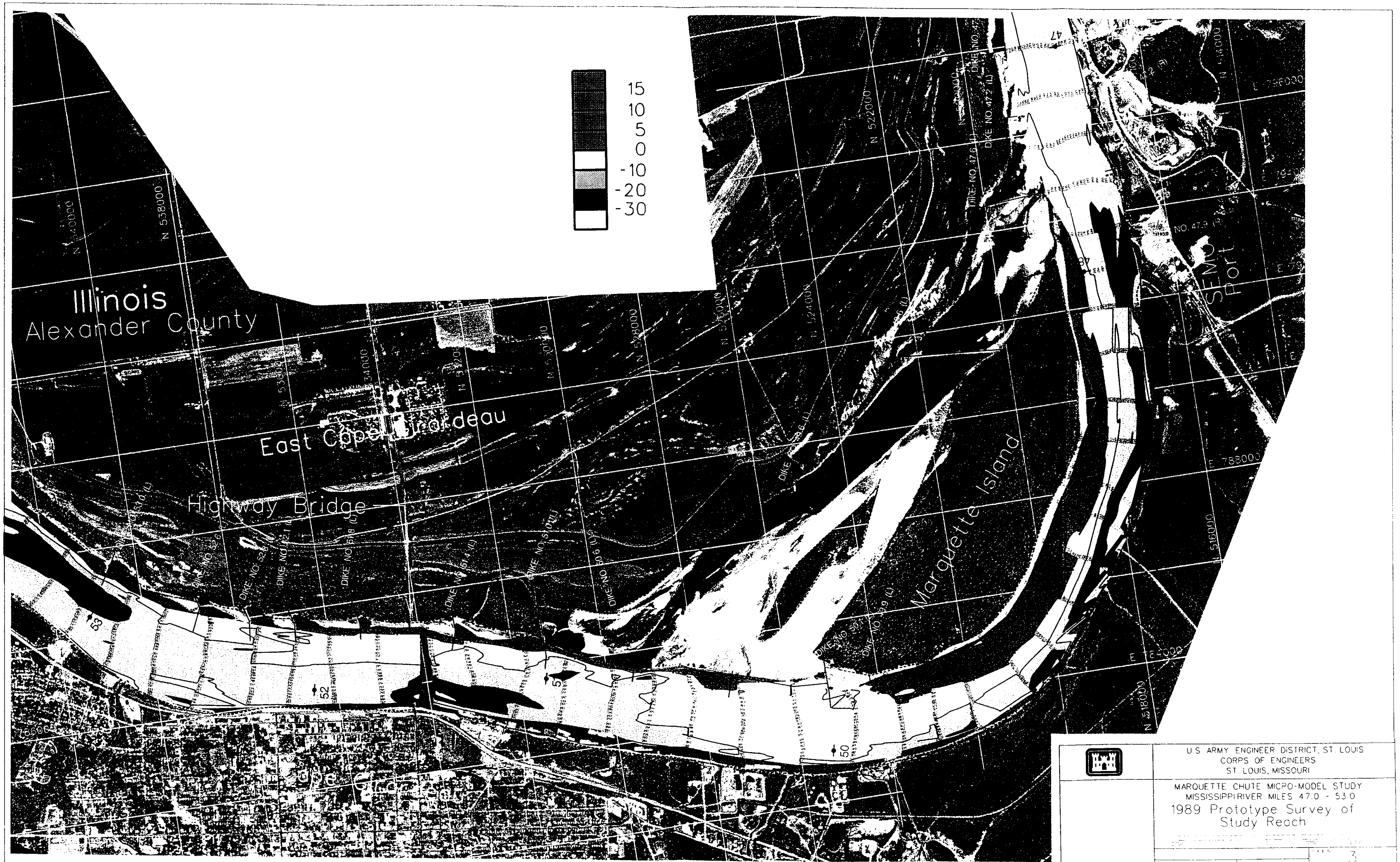
MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0
1995 Prototype Survey of
Marquette Chute

2



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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

1989 Prototype Survey of Study Reach

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MISSISSIPPI RIVER MILES 47.0 - 53.0

1995 Prototype Survey of Study Reach

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MISSISSIPPI RIVER MILES 47.0 - 53.0
1996 Prototype Survey of
Study Reach

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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Marquette Chute

PLATE NO 6

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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Marquette Chute

PLATE NO. 7

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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Marquette Chute

PLATE NO 8

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	MARQUETTE CHUTE MICRO-MODEL STUDY MISSISSIPPI RIVER MILES 47.0 - 53.0 Photograph of Marquette Chute
	PLATE NO 9

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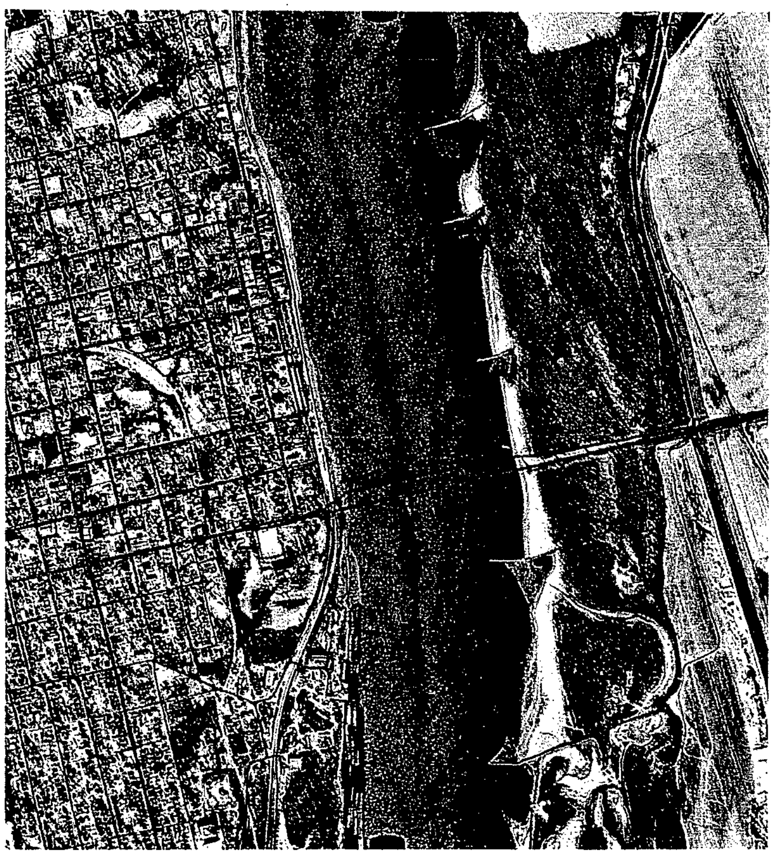
MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Marquette Chute

PLATE NO 10



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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Ice Photograph of Cape Girardeau Cityfront

PLATE NO 11

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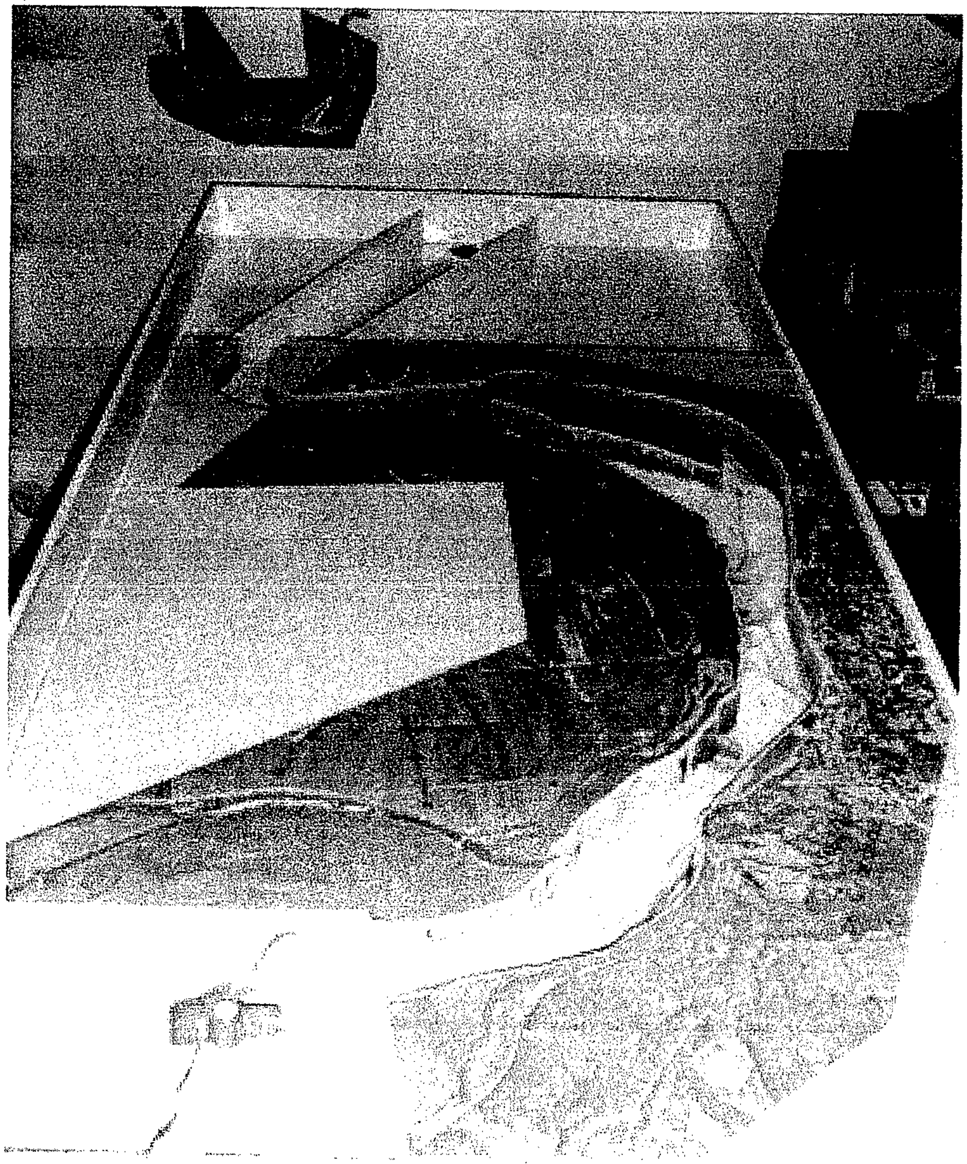
MISSISSIPPI RIVER MILES 47.0 - 53.0

Ice Photograph of Cape Bend

PLATE NO. 12



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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Photograph of Marquette Chute Micro Model

PLATE NO 13

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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0
Base Test
Without Bendway Weirs

Plot Scale: 1in = 3000 ft | Plot Date: 10 Sept 1997 | 14


15
10
5
0
-10
-20
-30
N
Illinois
Alexander County
East Cape Girardeau
Highway Bridge
Marquette Island
SEMO Port
CAPE BEND BENDWAY WEIR SYSTEM
DIKE NO. 47.2 (L)
DIKE NO. 47.6 (L)
DIKE NO. 49.9 (L)
DIKE NO. 50.1 (L)
DIKE NO. 50.5 (L)
DIKE NO. 50.6 (L)
DIKE NO. 51.0 (L)
DIKE NO. 51.4 (L)
DIKE NO. 51.8 (L)
WEIR NO. 47.9 (R)
WEIR NO. 48.5 (R)
WEIR NO. 48.6 (R)
WEIR NO. 48.7 (R)
WEIR NO. 48.8 (R)
WEIR NO. 48.9 (R)
WEIR NO. 49.0 (R)
WEIR NO. 49.2 (R)
WEIR NO. 49.3 (R)
WEIR NO. 49.4 (R)
WEIR NO. 49.5 (R)
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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0
Base Test
With Bendway Weirs
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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative A

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MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative B

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MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative C

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MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative D

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ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative E

20

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative F

21

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative G

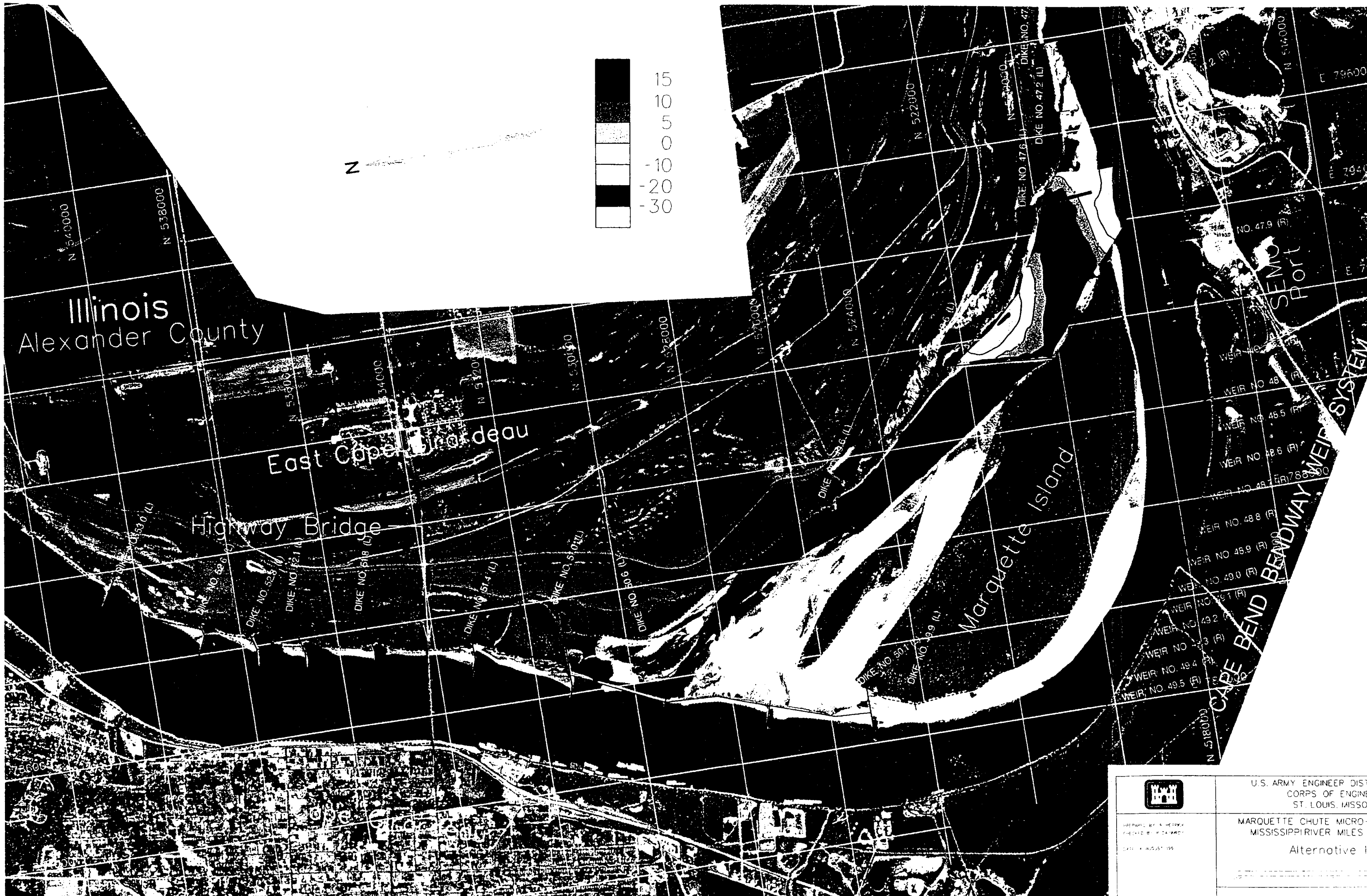
22

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative H

23



U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative I

24

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative J

25

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative K

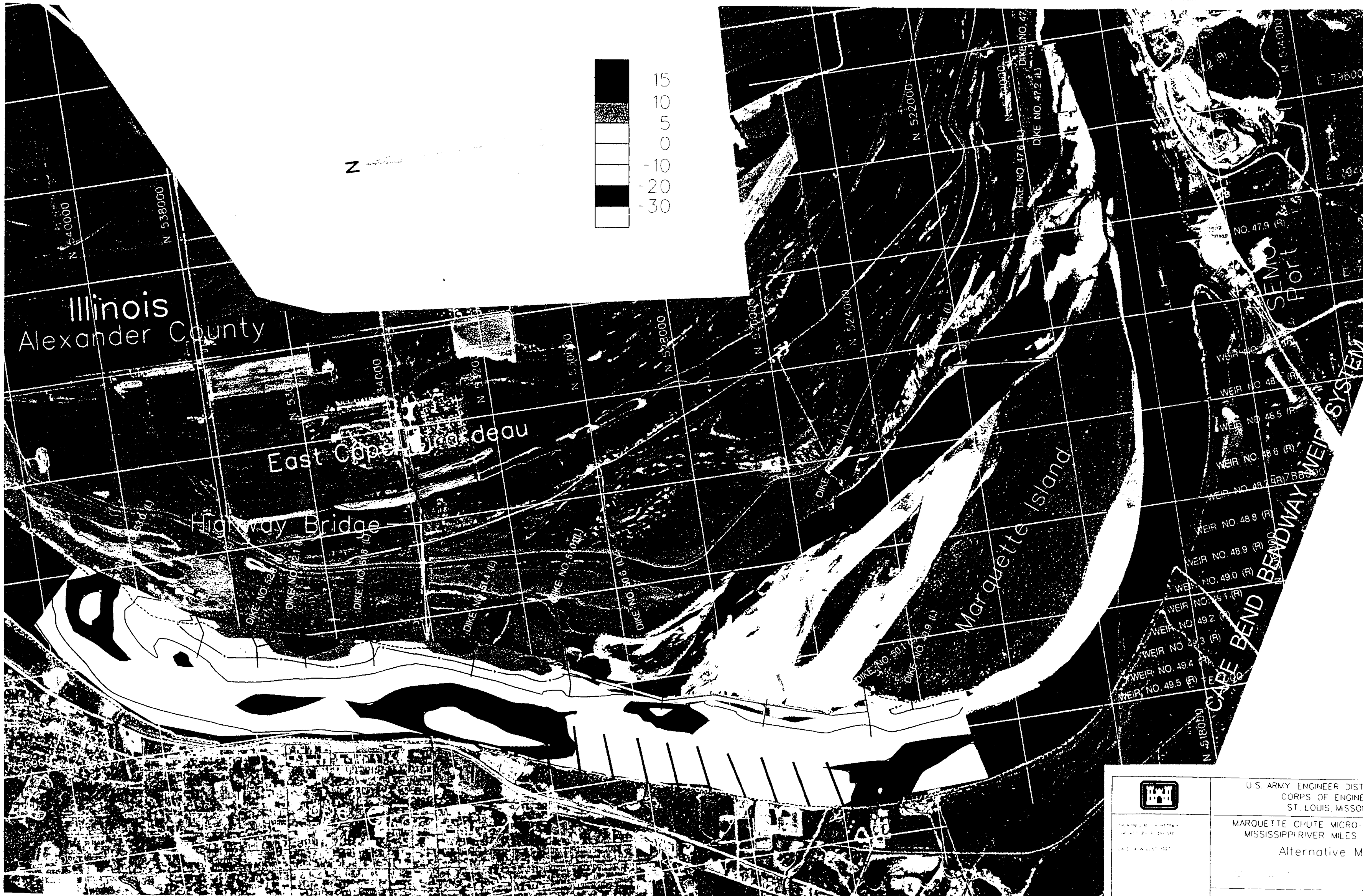
26

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative L

27



U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative M

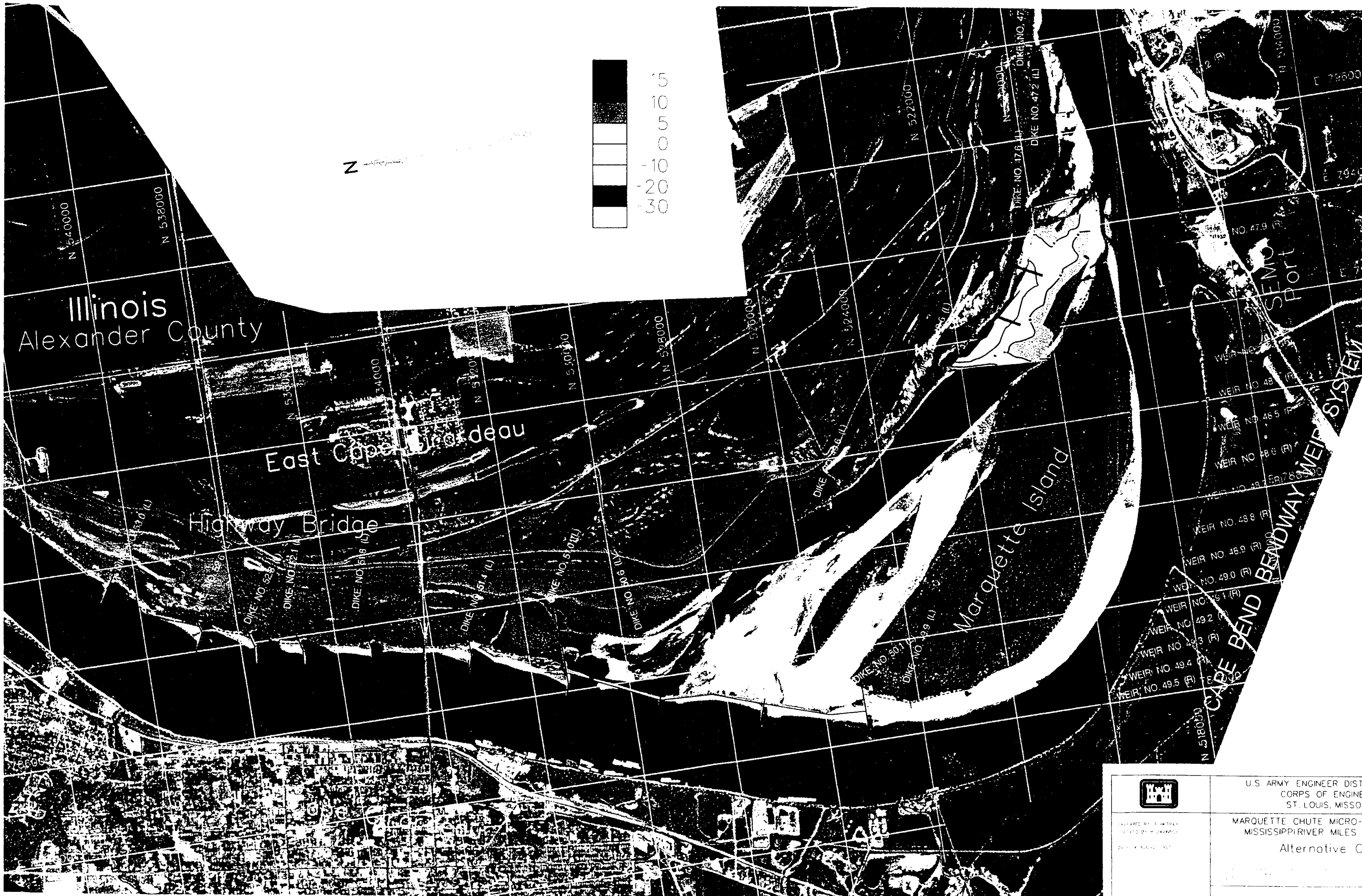
28

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative N

29

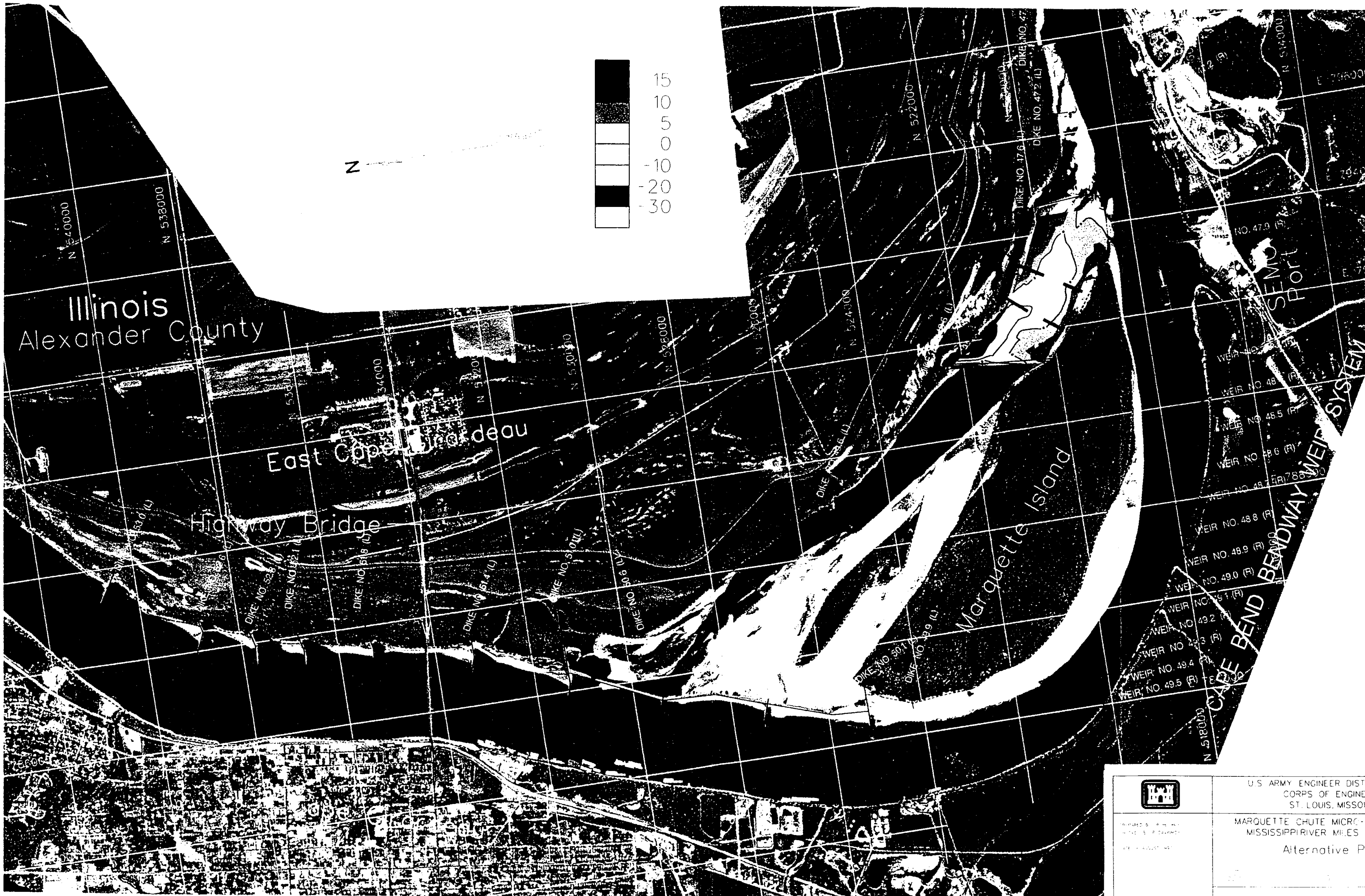


U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative 0

30



U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MARQUETTE CHUTE MICRO-MODEL STUDY
MISSISSIPPI RIVER MILES 47.0 - 53.0

Alternative P

31